On the Social Role of Computer Communications

ROBERT M. FANO, FELLOW, IEEE

Invited Paper

Abstract—**Computer-communication systems appear essential to meeting many needs in our society resulting from greater interdependence and complexity of operation and from rising expectations. There are, in principle, different ways of utilizing them for the same purposes, with radically different social consequences. The choice, which amounts in effect to a social decision, is, in practice, severely restricted by the computer hardware and software and by the communication facilities that happen to be available at the time. The paper discusses some of the pressures that lead to more widespread use of computers in the operation of society and illustrates how specific characteristics of computer-communication systems may influence social trends and, in particular, individual freedom.**

THE "MARRIAGE" of computers and communication has been celebrated and consummated. By now the honeymoon is over and the two partners are beginning to face the realities of their interdependence.

Electrical communications systems have extended our senses by enabling us to reproduce at a distance printed text, then sound, and finally pictures. These capabilities have greatly facilitated the communication process (in a broad sense) on which the functioning of organized society depends. Distance no longer limits communication within society; instead, the limiting factor is the ability of people to control, comprehend, and utilize the information that is being transmitted. Now it is the human mind that needs to be extended. This is where computers come into the world of communication.

The utilization of computers has followed a very different path. They were originally developed to act as fast calculating machines, but soon thereafter their usefulness as data processors became evident. This led to their widespread use in automating clerical operations.

It was then discovered that they can act, through close man–machine interaction, as skillful assistants to people in a great variety of intellectual activities from text editing to engineering design and from browsing through very large files to formulating and solving very complex problems. It is now becoming apparent that computers could facilitate in a major way communication within society with respect to just those functions that have been performed in the past by people and that are now overwhelming them. Not only could information originating from different sources be merged, restructured, and selectively disseminated to meet individual needs, but people might be able to interact in real time through computers "in the presence of" information that can be consulted and amended by them, either jointly or independently. Furthermore, information stored in a computer may include procedures as well as data, and therefore it may represent dynamic models of situations that have in the past been difficult to record on a static medium, such as paper, for transmission to others.

In order to exploit the computer's potential for facilitating communication within society, it is essential that computers be able to communicate easily with people and with other computers. In other words, it is essential that computers be embedded in a communication network. Of course, we cannot expect communication systems and computers in their present form to fit each other's needs and the objectives of the resulting computer-communication system. They will have to evolve in new directions, and so will have to evolve the legal, regulatory, and economic environment in which they exist. This evolution has just begun. Yet strong pressures on private and public organizations have led to the implementation of a multitude of computer-communication systems employing existing facilities, equipment, and techniques without much regard for their long-term social consequences. In effect, a nervous system of society is being developed piecemeal, on an *ad hoc* basis, to satisfy local needs. The task of understanding in depth the role of computer-communication systems in the operation of society, of evolving suitable policies in their respect, and of guiding their development from a social, economic, and technical standpoint, is a gigantic one. The following are examples of sociotechnical aspects of the task confronting us.

THE PRESSURE OF NUMBERS

A major force that has led to the use of computers in the operation of society is the growing volume of transactions of various types that must be handled. For instance, the Bank of America was led, in the middle of the 1950's, to pioneer in the use of computers by the realization that manual handling of checks would have required, in the foreseeable future, the entire adult population of California [1]. It is clear by now that, if computers were not available, the level of activity attainable in many segments of society would be strictly limited by the fraction of the population that could be devoted to the necessary bookkeeping tasks. It is not generally realized, however, that a similar limitation is beginning to emerge with respect to tasks of a substantially higher intellectual character, and that unless we succeed in circumventing it through proper exploitation of computers, the operation of society may well crack under the weight of its own complexity.

We hear many complaints about inadequacy of medical care, of education, and of many other services. These inadequacies are usually blamed on a variety of factors, such as lack of funds, incompetence, poor planning, or resistance to change. It may well be, however, that these factors are merely symptoms of a more fundamental limitation, namely, that society does not possess the human resources necessary to perform adequately all the necessary tasks, particularly in view of its growing complexity and the rising expectations on the part of the population. It is by no means obvious that a society can provide itself with all the specialized services that it needs according to present-day standards. Certainly, there

Manuscript received October 12, 1971; revised June 19, 1972.

The author is with the Massachusetts Institute of Technology, Cambridge, Mass. 02139.

is some limit to the amount and quality of such services, although we do not know how our expectations compare with it. Can this limit be circumvented?

STORING KNOWLEDGE

Part of the problem that we face stems from the fact that providing specialized services requires a great deal of knowledge and experience that cannot be readily transferred from one person to another. A substantial fraction of a person's life is devoted to acquiring them, in spite of the fact that many other people already possess them. Could a good part of this knowledge and experience be stored in computer programs and made available on demand? It is, of course, true that every computer program stores some human knowledge. However, it is usually knowledge of very limited general value. Could truly significant knowledge be stored in a program so that a computer could perform tasks requiring real intellectual skills? This has been accomplished in a few instances.

A good example is symbolic integration, that is, nonnumeric evaluation of indefinite integrals. As a result of contributions by several people over more than a decade, there exists now a complex of programs that can perform symbolic integration with a skill comparable to that of a very competent mathematician [2]. It is important to note that symbolic integration usually involves many steps, each consisting of the application of one of several well-known techniques. However, there are no precise rules for deciding which technique should be used in each particular instance. One must resort to a trial-and-error process, guided by mathematical judgment built on experience. In other words, symbolic integration is a true intellectual skill that requires considerable effort to acquire, and that can be easily lost from lack of practice.

It is important to note that storing knowledge into a program does not interfere with people acquiring it. On the contrary, it gives them a choice not previously available. They can use the program directly to accomplish their goals, or they can learn from the program the techniques and skills that it employs. In fact, it would be easier to learn from a program than from a book, because the program could guide the learner in his work, correct his mistakes, and answer his questions, much as an instructor would. The potential is clearly there, but much remains to be done before a significant fraction of human knowledge could be stored in computer programs. In particular, we cannot realistically expect that the people that possess the knowledge will develop the appropriate programs from scratch. It ought to be possible for them to transfer their knowledge to a general-purpose program by making statements and answering questions more or less as they would with another person.

MASS PRODUCTION OF SERVICES

Another part of the problem of increasing the quantity and quality of the services that society can provide itself with is best understood by analogy with the mass production of goods. The techniques of mass production have increased not only the quantity of goods available, but also their quality. Specifically, the quality of mass-produced goods is limited only by the total knowledge and capabilities of the society, while the quality of the goods produced by an artisan is strictly limited by his own knowledge and skill. With respect to services, we are still at the artisan stage. The quality of the services that we can obtain are still limited primarily by the knowledge, experience, and skill of the person that provides them, whether physician, teacher, or repairman. The average quality is far from satisfactory, and still the supply is inadequate to meet the needs of the entire population. What is needed, by analogy, is mass production of services, that is, a way of providing services that makes their quality consistent with the total knowledge and capabilities of the whole society, and their availability adequate to meet the needs of the entire population. For this purpose, information, instead of matter, must be transported and brought to bear on a specific situation, where and when the need arises. Thus a widespread and economic computer-communication network is clearly essential to the mass production of services, just as a widespread and economical transportation network has proved to be essential to the mass production of goods.

INFORMATION AND CONTROL

The services that are needed include access to information and advice on a great variety of matters that are essential to steering oneself safely and in a personally rewarding manner in a very complex environment which changes at a rapid rate. The fact that obtaining adequate information and advice is often prohibitively costly in time and money has consequences that transcend personal frustrations and injustices.

Control is a necessary function in organized society. It is most effectively exercised at the local level, where detailed information is readily available. However, it cannot be properly exercised out of the context of broader objectives and other activities with which coordination must be achieved. If knowledge of the context is not available locally, specific instructions must be issued from where the context is understood. Thus the present trend towards centralization of control can be seen as a direct consequence of the growth of interdependence and our inability as individuals to maintain a working knowledge of an increasingly complex environment. On the other hand, centralization of control runs into informational problems of its own. Specific instructions, to be effective, must be based on detailed local information. Collecting timely data about a broad spectrum of activities and generating from them detailed control information can quickly become an unmanageable task. Furthermore, information that can be readily acquired and utilized locally may be very difficult to represent for use elsewhere.

Are the informational problems of centralized control easier to solve than those of distributed control, or vice versa? The evidence emerging from the design of complex computer systems and communication networks seems to favor distributed control over central control. One reason for this is that less information needs to be explicitly stored. Distributed control is clearly more consistent with individual freedom and autonomy, but cannot survive without adequate information flow. Central control is undesirable from a personal standpoint, but its survival is much less dependent on information. Computer-communication systems will be required for either type of control, but their characteristics are bound to be quite different in the two cases. Thus if we follow the path that appears easier and safer in the short run, we may find ourselves in the future where we do not want to be, yet no longer able to change direction.

COMPUTERS AND PEOPLE

There is an important lesson that computer people had to learn during the last decade, at considerable cost in money, time, and frustration. The lesson is that it is inappropriate to design or evaluate computer equipment out of the context of the software that provides the interface to its users. The reason is simple. The equipment characteristics limit in a major way the interface characteristics that can be obtained. An extension of the same lesson remains to be learned, namely, that it is inappropriate, and in this case dangerous, to design or evaluate a computer system out of the context of the community of people that will be affected by its use, either directly or indirectly. The reason is equally simple. The characteristics of the computer system limit in a significant way the structure and mode of operation of the associated community of people and thereby influence the attitude and behavior of the individuals that comprise it. In turn, the characteristics of the community influence the evolution of the computer system itself. Because of the resulting feedback loop, the overall system consisting of hardware, software, and people may acquire unintended and possibly undesirable characteristics of its own.

In other words, when we employ computers in any task involving people, we make in effect a social decision, the consequences of which may be far reaching. The class of social decision that can, in fact, be implemented at a given time is largely defined by the specific characteristics of the available computer systems and the related facilities and techniques that are at our disposal. It may well be that all the options available at a particular time have undesirable social consequences. Yet the help of computers may be so urgently needed that disregarding such social consequences may be regarded as the lesser of two evils. The point is that, once the technology is specified, our freedom of choice in the utilization of computers may well be very limited. Our freedom of choice is instead widest and most effectively exercised ahead of time when we select the characteristics of the technology that we intend to make available in the future.

MAN–MACHINE INTERACTION

A set of characteristics of computer systems that are very important with respect to potential social effects are those that influence the ease, flexibility, and intimacy of man–machine interaction from an intellectual as well as a physical standpoint. If the activities carried out by computers cannot be readily monitored and guided by people, and if human processing of information cannot be easily intermixed with computer processing, computers tend to become unchallengeable authorities with respect to the functions they perform. As a simple example, when data are stored on magnetic tape or on any other storage device within a computer system, they are removed from direct human inspection. If the computer system does not provide convenient means for browsing through them, it becomes difficult and costly to locate errors and correct them. As a result, the data and the conclusions reached from them become unchallengeable simply because it would be too time-consuming or costly to challenge them.

Man–machine interaction is of particular importance when computers are employed in any facet of the operation of society involving problem solving and decision making. It is didactically convenient, when explaining how a problem has been solved, to discuss first its formulation and then its solution. However, the separation into distinct phases does not correspond to what actually takes place. Instead, problem formulation and problem solution proceed concurrently most of the time, and this is so not by choice but by necessity. One cannot be sure that a problem has been properly formulated without exploring some of the consequences of the formulation. The fact that an important constraint has been forgotten often becomes evident through the examination of a solution that is logically correct but clearly unacceptable. Since computers are very powerful aids to problem solving, while problem formulation lies inherently in the human domain, the ability to establish close collaboration between man and computer becomes of crucial importance. If means for establishing this close collaboration are not available, some aspect of the formulation is very likely to be delegated by default to the computer. The delegation may take the form of forcing a problem into a mold in which it does not fit, or of accepting an inadequate solution because of time limitations or out of sheer frustration. If the problem is an important one, the consequences of delegating its formulation to computers may be quite serious and possibly tragic. The late Prof. Norbert Wiener used to warn us of this point way back in the late 1940's [3]. Computers, he used to say, are literal minded just like magics: they solve the problem that has been presented to them, not the one that ought to have been presented. Such warnings were usually followed by some tale of magics that made the point all too obvious.

COMMUNICATION THROUGH COMPUTERS

Another set of characteristics of computer-communication systems of considerable importance are those that facilitate people-to-people communication [4] over time and intellectual barriers as well as distance. These are the characteristics necessary to provide good coupling to people as members of an interacting community above and beyond good coupling to people as individuals. A system feature of major importance in this respect is the ability to share data and procedures under flexible and secure control. Not only is this ability essential to any computer-aided activity involving close collaboration between people, but it is bound to influence in a major way the structure and mode of operation of any community in which important functions are dependent on the use of computers.

If secure control over access to information cannot be exercised selectively within a computer system, it must be exercised externally by traditional means. This implies that all programs must be individually analyzed and approved before execution; checking the output would not be sufficient because improperly obtained information could be easily disguised. In practice, access to information and to computers would have to be severely limited, and control in individual organizations and in society as a whole would, by necessity, become increasingly centralized.

The sharing of information within a computer system presents difficult operational and semantic problems, even if the need for controls is disregarded. Information must be identified, retrieved from wherever it is stored, and used in a proper manner in conjunction with other information. If a computer system is to act as an information broker, it must be able to converse intelligently about the information it contains in its memory. While significant progress is being made in this direction, much remains to be done. In the meantime, we must be wary of plans to circumvent these difficulties through the imposition of rigid formats. Forcing situations into a preestablished mold often results in dangerous distortions of reality.

The protection of individual and organizational privacy is not the only objective that requires dependable means for insuring the integrity of the information stored in a computer system and for controlling its use. Controls are also needed to implement contractual agreements between developers of useful software and data bases and users of these facilities. Also, uncontrolled collection, storage, and dissemination of information lead necessarily to "pollution" of the information environment, a phenomenon which is already having disturbing if not serious consequences. Finally, public safety requires that secure control be exercised over information that could endanger the public, for instance, by causing panic or by enabling or fostering illegal activities.

The protection of individual privacy presents some special problems because of the large number of people involved and the proliferation of files containing information about individuals. The presence in a file of incorrect, incomplete, or misleading information is at least as dangerous to an individual as the possibility of unauthorized or otherwise improper disclosure of information about him. Thus it is not only necessary to protect personal information against malicious or accidental modifications; we must also make it possible for each individual to check the accuracy of information kept about him without infringing upon the privacy of others and without an unreasonable expenditure of time and effort on his part. It is difficult to conceive how this could be accomplished without providing direct access to the computer system in which the information is stored and without reducing through sharing the present proliferation of similar files.

The development of means for controlling the use of information within computer systems is still in its infancy. A few time-sharing systems exist in which access to individual files can be granted and withdrawn selectively for reading, writing, or executing, but the vast majority of computer systems do not permit even this basic form of control. Yet much more elaborate forms of control are needed. For instance, it is not sufficient to specify who may have access to a particular data file; it is also essential to place restrictions on the information that may be extracted from it. Furthermore, means are needed for controlling and auditing the controls themselves, according to externally established lines of authority and responsibility.

It was very encouraging at the 1972 Spring Joint Computer Conference to hear from the Chairman of the Board of IBM of the commitment IBM is making to data security in its systems. This is the first recognition on the part of a computer manufacturer that the problem of data security needs immediate attention. A similar commitment to action is also needed from the other segments of the computer-communication industry. The implementation of adequate facilities for controlled sharing of information presents very difficult problems even within the limited context of individual computer systems. These problems become substantially more difficult in the broader context of computer-communication networks, where programs executed in one computer may call on programs or data stored in other computers. The task confronting us is indeed very large and very complex, and the consequences of not devoting to it the necessary resources could be extremely serious.

KNOWLEDGE AND POWER

Computers provide access to knowledge, and knowledge restricted to a segment of society can be transformed into power over the rest of society. Thus unless computers are made truly accessible to the population at large, there will necessarily develop a dangerous power gap between those who have access to them and those who do not, and particularly between organizations, public or private, and individuals.

The ability to share knowledge through computer systems may well play in the future a role analogous to that of the printing press. Before the invention of the printing press, literacy was limited to a small segment of the population. This is not surprising because most people read what other people write. By now, it is generally accepted that literacy is a prerequisite to effective participation in the life of society. On the other hand, there is very little incentive today to learn how to exploit the capabilities of computers, because the data stored in computer systems and the programs necessary to extract relevant information from them are not readily accessible. Yet computer-communication networks are on their way to forming a new nervous system of society. How can individual citizens play their rightful role in society without having access to it?

It seems essential, therefore, that we redirect our efforts toward assisting individuals in their daily life and facilitating communication within society. This implies, for instance, that we must invest in the development of a computer-communication network capable of serving the public at large. It must be a single interconnected network in order to avoid introducing artificial barriers between people and between different aspects of their individual activities. This does not imply that the network must be owned and operated by a single organization, nor does it imply anything specific about the structure of the network and the distribution of processing and storage capacity. It does imply, however, that the network must look to each user as a single system, in the sense that he must be largely unaware of and unaffected by the internal structure and economic organization of the network.

In spite of recent efforts in the direction of general-purpose computer-communication networks, the computer and communication technologies and the legal and regulatory environment are largely ill suited to this objective. The trend is, instead, in the direction of dedicated special-purpose systems unrelated to and incompatible with one another. If this trend continues for much longer, it may become very difficult in practice to merge these special-purpose systems into a single general-purpose network. It is well to remember in this regard that, while wire telephony has evolved into a single general-purpose network, radio communication has evolved, instead, into an aggregate of special-purpose incompatible systems that would be very difficult, technically and politically, to merge into a single coherent network.

Making computer-based services available to the public implies much more than the development of the necessary hardware facilities. The task of making a computer-communication network useful to the public and also economically and intellectually accessible to the entire population is indeed a gigantic one that will require considerable effort over a long period of time. Unless we focus on this goal very soon, the growing gap of knowledge in society is likely to become so wide and the resulting gap of power so entrenched that it will be extremely difficult, if not impossible, to return to anything resembling a democratic society.

WHERE TO?

This paper has attempted to illustrate two basic points. The first point is that the structural and operational complexity of modern society and the growing interdependence within it are straining our ability to comprehend and deal successfully with the multitude of problems that we face individually and collectively. The computer and communication technologies will not, by themselves, solve our problems, but it is very unlikely that we will be able to solve them without substantial help from them. In practice, their help is being increasingly sought in almost every aspect of the operation of society, and their utilization has already had a marked effect on many of them. This trend is bound to continue simply because there does not seem to be anywhere else we can turn for help in preventing society from collapsing under the weight of its own complexity.

The second point is that the growing utilization of computer and communication technologies will undoubtedly have a major influence on the operation of society, on our daily lives, and even on our values and our perception of the world. The character of these social effects, however, will depend largely on how we will choose to develop and utilize the computer and communication technologies. The choice, roughly speaking, is between automating those functions in society that people seem unable to continue to perform adequately and helping people to cope successfully with the growing magnitude and complexity of the tasks that confront them. The present trend is toward automation of functions in a way that lessens significantly human control over them by removing the pertinent information from easy access on the part of people. This trend is not the result of a conscious choice, but rather because it would be too inconvenient, or too uneconomical, or even impossible to do otherwise in view of the technology that happens to be available at this time. Continuation of this trend is very likely to lead to a society operated by a rigid bureaucracy whose power will stem from widespread surveillance and control over information, that is, to a society of the "1984" type. This is most likely to occur unintentionally as a result of the actions of many well-meaning people attempting to solve the problems they face in the best way they know how at the time. The opposite choice involves exploiting the computer and communication technologies to augment the intellectual capabilities of people and to facilitate communication between them, with the objective of enabling society as a whole to operate effectively at a much higher level of complexity. A major result of the power revolution has been the development of a great variety of devices that have augmented the power, the precision, and the skill of our muscles. The computer and communication technologies can, in a similar way, augment the power, the precision, and the skill of our mind. Moving in this direction, however, will require a conscious and determinate choice, because most short-range considerations, economical, technical, and political, seem to militate against it. In particular, we must consciously shape our technology in this direction and make sure that appropriate technical capabilities will be available when needed, rather than make do with whatever happens to be available as a result of short-range local considerations.

Even in the best of circumstances there are going to be many conflicts between new modes of operation in society and traditional habits of people. As frustrating as these conflicts may be to those of us who are fond of technical innovation, they are much more frustrating to the people at the receiving end, who do not wish to devote the intellectual and emotional energy required to change their outlooks and habits. Thus the concluding plea is for awareness of the individual, of his needs, his feelings, and particularly his pride as a human being. Without such an awareness the impact of computers and communication on society may turn out to be a nightmare.

REFERENCES

[1] J. Weizenbaum, "The two cultures of the computer age," *Technol. Rev.*, p. 55, Apr. 1969.
[2] J. Moses, "Symbolic integration," Mass. Inst. Technol., Cambridge, Mass., Tech. Rep. MAC-TR-47 (thesis), Sept. 1967.
[3] N. Wiener, *The Human Use of Human Beings.* Boston, Mass.: Houghton Mifflin, 1950, p. 212.
[4] J. C. R. Licklider and R. W. Taylor, "The computer as a communication device," *Sci. Technol.*, no. 76, p. 21, Apr. 1968.